Dear Editor,

We appreciate the prompt reviews and would like to thank the reviewers for insightful comments and suggestions on our manuscript entitled "What is the cause(s) of positive ozone trends in three megacity clusters in eastern China during 2015–2020?" (MS No.: egusphere-2023-1088). We have carefully considered all comments and suggestions. Listed below are our point-by-point responses to all comments and suggestions of Reviewer #2 (Reviewer's points in black, our responses in blue).

Anonymous Referee #2

The authors explore the potential mechanism driving the observed increase in surface Ozone during 2015-2020 over three megacity clusters in eastern China. Observational data for several pollutants from the Chinese National Environmental Ministry of Environmental Protection and Tracking Air Pollution in China dataset are analyzed in the paper to explore the trends in surface ozone over the study regions for the period of interest. Further, reanalysis data from ERA5, NCEP and NCAR are used to investigate the correlation between the evolving weather systems and the positive ozone trends. The study approach is mainly based on statistical analysis of observational data.

General comments:

The paper presents the meteorological conditions conducive to ozone formation (e.g., increased solar radiation) as potentially driving the positive ozone trends, rather than an increase in the anthropogenic emissions or a combination of both. While this is an important and interesting topic, some concerns need to be addressed in the paper before publication. The paper section structure, wording and logic, and the overall presentation can be further improved. More information needs to be included in the paper to further support the hypothesis that weather systems and changing meteorological conditions are responsible for observed increase in O_3. Please consider the following suggestions:

1. List the processes (e.g., photochemistry) and precursors involved in the production

of ozone, explicitly with tables and/or graphs (e.g., EKMA ozone isopleth diagram). Explicitly show the correlation (even if a weak correlation) between emissions of precursors (e.g., NOx, VOCs) and O_3 levels.

Response:

A highly simplified O_3 production scheme can be shown as follows:

$$OH + CO(VOC) + O_2 \rightarrow HO_2(RO_2) + CO_2$$

$$HO_2(RO_2) + NO \rightarrow NO_2 + OH(RO)$$

$$NO_2 + hv(\lambda < 420nm) \rightarrow NO + O(^3P)$$

$$O(^3P) + O_2 + M \rightarrow O_3 + M$$

Net: $$CO(VOC) + 2O_2 + hv(\lambda < 420nm) \rightarrow CO_2 + O_3 + (RO)$$

Where NO_x (NO + NO_2) and HO_x (OH + HO_2) act as catalysts for O_3 production. Generally, the O_3 production tends to go up with the catalysts. In reality, other reactions can become competitive with the reactions above under high NOx conditions, and thus reduce the O_3 production efficiency. For instance, the reaction $OH + NO_2 + M \rightarrow HNO_3 + M$ can reduce HO_x and O_3 at high concentrations of NO_2. In addition, the titration of O_3 by NO becomes effective when NO emissions are high.

To explicitly show the correlation between emissions of precursors and O_3 levels, we list the correlation coefficient as follows:

Table R1. Correlation coefficients between precursors and O_3 in three megacity clusters.

	BTH	YRD	PRD
NOx	-0.30(p-value =0.56)	-0.82(p-value =0.04)	-0.03(p-value =0.96)
VOCs	-0.59(p-value =0.22)	-0.15(p-value =0.78)	-0.28(p-value =0.58)

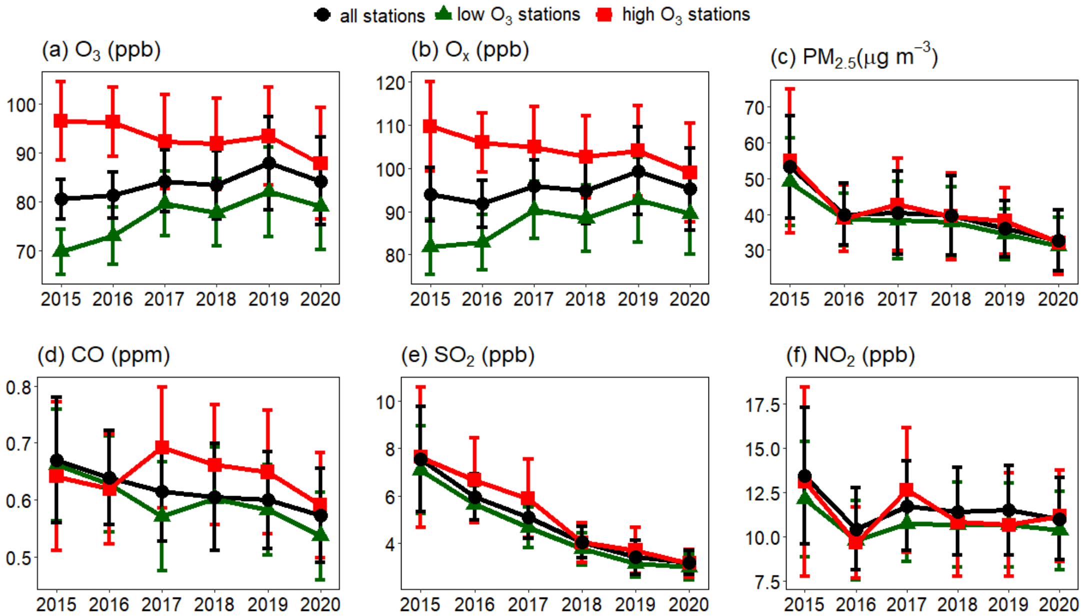

Figure R1. Annual mean concentrations of maximum daily 8-hour average O_3 in YRD during O_3-exceeding days for all stations (black), high O_3 stations (red) and low O_3 stations (green) (a), same as (a) except for Ox (b), $PM_{2.5}$ (c), CO (d), SO_2 (e), NO_2 (f).

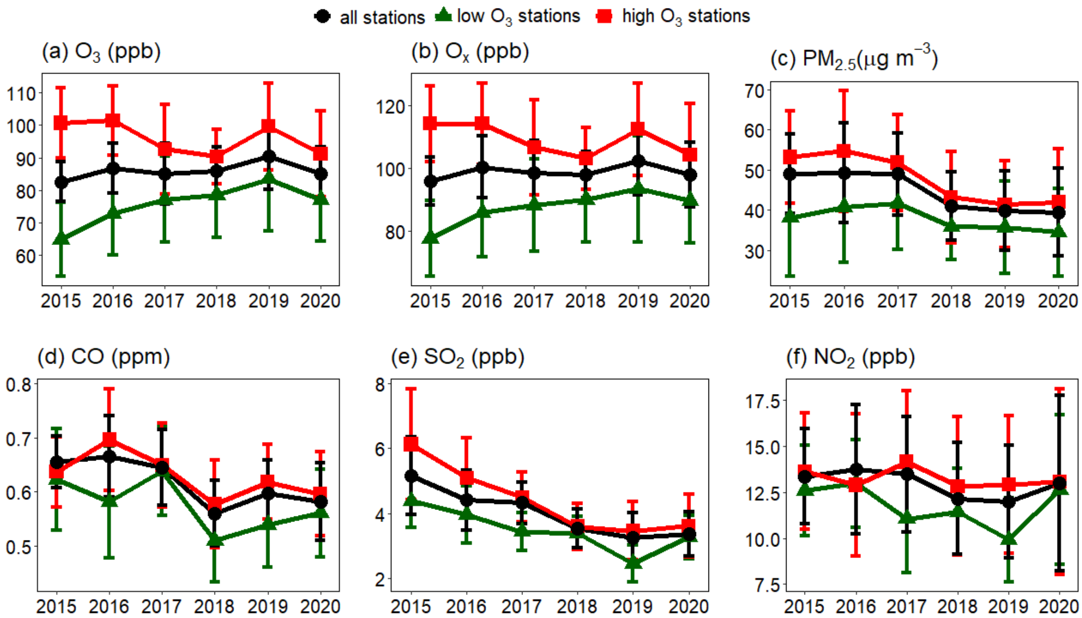

Figure R2. Annual mean concentrations of maximum daily 8-hour average O_3 in PRD during O_3-exceeding days for all stations (black), high O_3 stations (red) and low O_3

stations (green) (a), same as (a) except for Ox (b), $PM_{2.5}$ (c), CO (d), SO_2(e), NO_2 (f).

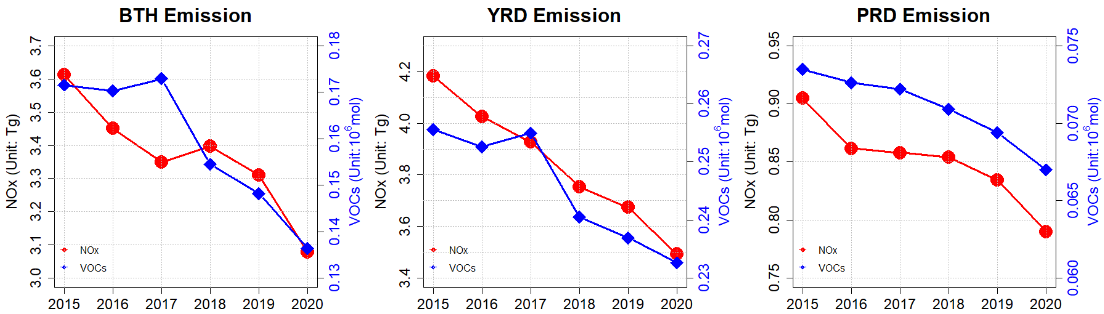

Figure R3. NOx and VOCs emissions in the BTH, YRD and PRD regions from 2015 to 2020.

2. Compare the meteorological conditions to longer range time periods to clearly demonstrate that conditions have evolved towards increased ozone production. Comment on why these conditions have changed.

Response:

We appreciate this suggestion. A similar comment was made by Reviewer 1, Main concern (4). We address this point by adding the following four paragraphs and two figures (Figs. 12 and 13) near Line 300:

"Hu W. et al. (2023), in collaboration with this study, conducted a statistical analysis to assess processes that contribute to high O_3 formation in PRD when TCs were present in the northwest Pacific. They investigated the impact of the distance between TCs in the northwest Pacific and PRD on the O_3 concentration in the PRD from 2006 to 2020. They found that the large numbers of consecutive O_3-exceeding days in 2017 and 2019 relative to 2015 were primarily attributable to the greater occurrence of downdrafts and stable atmospheric conditions brought about by mid-distance category TCs. This finding clearly establishes that changing frequency of mid-distance category TCs (i.e. changing meteorological conditions) is the cause of the increases in the numbers of consecutive O_3-exceeding days as well as the higher O_3 concentrations in PRD.

Ongoing study by our research group further shows that the mid-distance category TCs are predominately those TCs with tracks starting around the southern Philippines and ending near Korea and/or Japan. Since TC tracks in northwestern Pacific are strongly controlled by WPSH, we conclude that both Philippines-to-Korea/Japan track TCs and corresponding distribution and intensity of WPSH contributed to the higher consecutive O_3-exceeding days in PRD from 2015 to 2020.

Mechanically we propose that the O_3 concentrations at the high O_3 stations stayed close to a saturation level of about 100 ppb throughout 2015 to 2020, even under increased downdrafts and stable atmospheric conditions brought about by mid-distance category TCs. This saturation effect was the result of enhanced rates of atmospheric dispersion, dry deposition and photochemical loss at high O_3 concentrations, which were supported by modeling results (Li et al., 2012; Ouyang et al., 2022; Zhang et al., 2023). It is also consistent with theoretical consideration. While the low O_3 stations, where O_3 production were relatively small in 2015, experienced significant enhancements in the O_3 production (32 ppb in BTH, 12 ppb in PRD) from 2015 to 2017 because in the latter year the increased downdrafts and stable atmospheric conditions brought about by mid-distance category TCs were highly conducive to O_3 formation (Hu W. et al., 2023).

Following the analysis by Hu W. et al. (2023), the mean vertical velocity at 850 hPa during all O_3-exceeding days in PRD in 2015 (Fig. 12a) is compared to that of episodes with four or more consecutive O3-exceeding days in 2017 (Fig. 12b). Major features in Fig. 12 compare very well with those of Fig. 7. E.g. area with positive vertical velocity (downdrafts) in 2017 (red area in Fig. 12b), which was highly conducive to O_3 formation, was by far more widespread and greater in value than that of 2015 (red area in Fig. 12a), agreeing well with the greater high O_3 area of Fig. 7b (2017) than that of Fig. 7a (2015). This agreement confirms that the increase in O3 in PRD from 2015 to 2017 was caused by increased downdrafts and stable atmospheric conditions (meteorological conditions) brought about by TCs as suggested by Hu W. et al. (2023). The same plots for BTH are shown in Fig. 13. Features of Fig. 13 are highly consistent with those of Fig. 5. The same plot for YRD (Fig. S10) also showed more extensive and greater downdrafts in 2017 than 2015. However, the area of positive vertical velocity in YRD appeared to shift about 500 km to the east compared to the area of high of O_3 in Fig. 6b. Considering the uncertainty in evaluating the vertical velocity and that O_3 formation is also dependent on parameters other than the vertical velocity, the discrepancy is acceptable.

In summary of this section, the trends in O_3 in the three megacity clusters are critically dependent on the number of four or more consecutive O_3-exceeding days. In addition, Hu W. et al. (2023) found that the changing frequency of mid-distance category TCs (i.e. changing meteorological conditions) is the cause of the increases in the numbers of consecutive O_3-exceeding days as well as the O_3 concentrations in PRD. More importantly, our additional analyses of the mean vertical velocity at 850 hPa over the three megacity clusters (Figs. 12, 13 and S10) show that the increases in O_3 in all three megacity clusters from 2015 to 2017 were caused by enhanced downdrafts and stable atmospheric conditions (meteorological conditions) which were highly conducive to O_3 formation. The enhanced downdrafts and stable atmospheric conditions were brought about by TCs and associated WPSH. Here we bring up WPSH because it is well known that the tracks of TCs are influenced strongly by WPSH, and that WPSH affects strongly regional atmospheric dynamics and therefore O3 formation (Chang et al., 2019; Mao et al., 2020; Ouyang et al., 2022; Zhao and Wang, 2017)."

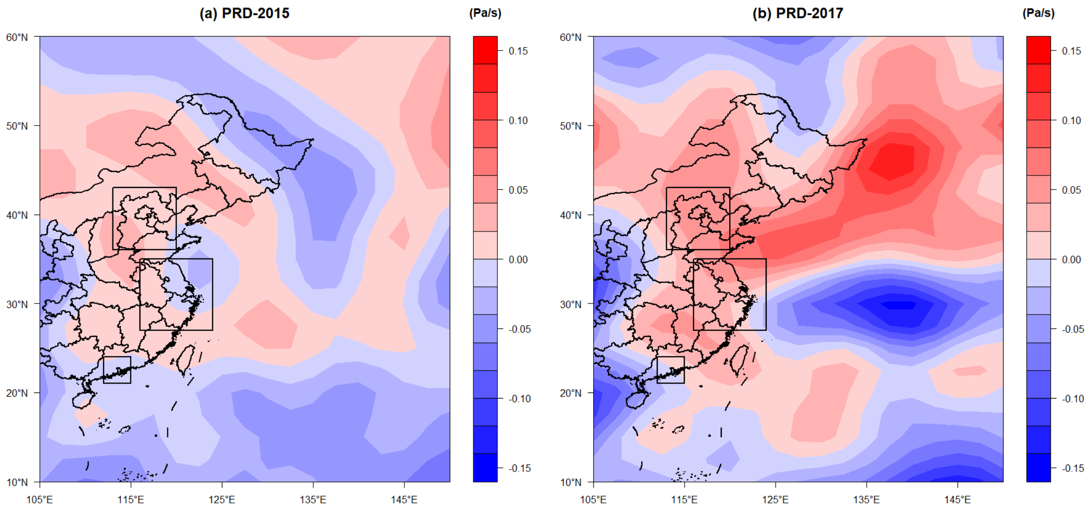

Figure 12. Mean vertical velocity at 850 hPa during O_3-exceeding days in PRD in 2015 (a) and during episodes with four or more consecutive O_3-exceeding days in 2017 (b).

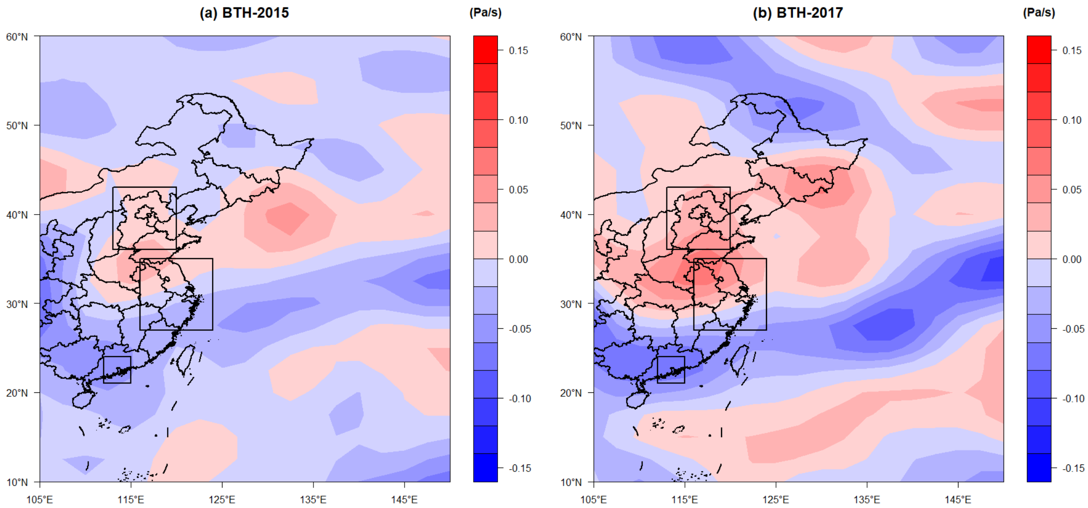

Figure 13. Mean vertical velocity at 850 hPa during O_3-exceeding days in BTH in 2015 (a) and during episodes with four or more consecutive O_3-exceeding days in 2017 (b).

3. Include information on how land use/development was changed during the same period, to compare against the spatial expansion of high O_3 from urban centers to surrounding regions (past vs current).

Response:

We did not discuss changes in land use/development during the study period in our manuscript for the following reasons:

(1) Over a relatively short time (7 years) frame, especially in already highly developed areas like BTH, YRD and PRD, significant changes in land use are not expected. Additionally, acquiring information on short-term land use/development changes is not practical due to lack of relevant data.

(2) In line with China's Technical Regulation for the Selection of Ambient Air Quality Monitoring Stations (on trial) (HJ 664-2013) (Ministry of Environmental Protection, 2013), it is imperative that ambient air quality monitoring stations strategically

incorporate considerations from both urban and rural development plans. This approach ensures that identified monitoring locations account for the evolving spatial patterns in urban and rural areas over time, guaranteeing their representativeness. These stations are tasked with objectively depicting ambient air quality levels and trends within a defined geographical area and providing an accurate assessment of the influence of pollution sources on local air quality. Additionally, these stations placements must factor in various environmental aspects such as physical geography, meteorology, as well as socioeconomic characteristics including industrial distribution and population density. Their purpose is to accurately portray the current state and future trends of air quality within key functional zones and primary sources of air pollution in the city. It's worth noting that from 2015 to 2020, the number of monitoring stations within the study area has remained constant, and the ability of these stations to reflect their surrounding conditions should likewise remain unchanged.

(3) The selection of different monitoring sites was not based on land use/development criteria but rather on the O_3 pollution levels at each site in the initial year of this study, which was 2015.

4. Authors acknowledge that their results are mainly based on statistical correlations and further investigation into causal relationships is needed, perhaps with a use of a chemical/transport model. I agree and I'd like to emphasize that this topic is a great case for a model-based investigation, although it might be out of scope for the current manuscript. Model scenario simulations, with different input emissions and for various meteorological conditions, are crucial for further investigating this topic. All models have limitations, but their power and capability in investigating air quality and transport scenarios cannot be dismissed.

Response:

Thanks for this insightful comment. Yes, we fully agree that a realistic 3-D model of O_3 would be an ideal tool to determine the relative contributions of emission and/or meteorology to the linear trends of O_3 in the three megacity clusters. We have tried many modeling studies on O_3 and have come to the recognition that current models have too large uncertainties and limitations to simulate the O_3 trends of the three megacity clusters realistically. To our knowledge, no modeling study has reported any successful simulation of the O_3 trends in the three megacity clusters.

Specific comments:

1. Line 23: "These favorable meteorological conditions greatly facilitated the formation of O_3" - suggests causal relationship, while only correlation is established in the paper…, please consider revising.

Response:

Please refer to our response to your general comment #2. In the extensive revisions in response to this general comment, we have linked mechanically the significant increases in the O_3 production in 2017 and 2019 to the enhanced downdrafts and stable atmospheric conditions associated with corresponding changes in TCs and WPSH in the northwestern Pacific.

2. Line 37: "The concentrations of air pollutants SO_2, NOx, CO, PM_{10} and $PM_{2.5}$ in China have been significantly reduced since 2013" – what about VOCs?

Response:

The emissions of VOCs have also declined since 2013 (Fig. R3). Because VOCs are not currently included in China's regular pollutants, their trends were not mentioned in the original manuscript.

3. Figure 1,2,3,4: What caused the reduction in 2020? The Covid19 pandemic related closures and slowed down activities perhaps? You can see the same reduction in Figures 2, 3 and 4. Is this related to decreased emissions of precursors in 2019-2020 or changing meteorological conditions?

Response:

In the three regions, the O_3 concentrations and O_3 exceedance days in 2018 were all lower than those in 2019, but were comparable to those of 2017 and 2020. These features suggest that changing meteorology rather than the 2020 COVID-19 pandemic was more likely responsible for the interannual variations in O_3.

In fact, there were many studies reporting that during the early stages of the COVID-19 lockdown in early 2020, O_3 concentration did not decrease but instead increased (Huang et al., 2020; Le et al., 2020). We believe that the decline in 2020 compared to 2019 was mainly due to changes in meteorological conditions. The number of rainy days from May to October in the BTH and YRD in 2019 was the lowest in 2015, and the radiation intensity was the highest during the same period. These meteorological factors contributed to the highest O_3 concentrations observed in 2019. In contrast, from May to October 2020, most regions in China experienced more precipitation, weaker radiation, and lower average maximum temperatures, creating meteorological conditions that were overall favorable for reducing O_3 concentrations (China Meteorological Administration, 2021).

4. Line 85: "time interval of 1 h" do you mean a temporal resolution of 1 h, or your data is for only a 1 hour interval?

Response:

Sorry for this confusion. "Time interval of 1 h" denotes a temporal resolution of 1 hour. In the revised manuscript, we have replaced "time interval of 1 h" with "temporal resolution of 1 h".

5. Line 93: "duration of O_3 pollution," please elaborate.

Response:

Thanks. It should be "duration of O_3 pollution episode", specifically talking about the number of days during which O_3 concentration continuously exceed air quality standards.

6. Line 93: "can be divided into consecutive O_3-exceeding days with four or more days…" - please explain why this particular division was used?

Response:

This division was based on the features in Fig. 3. There was no discernible trend in the sum of days of episodes with less than four consecutive days in the three regions from 2015 to 2020. The upward trends are primarily controlled by consecutive O3-exceeding episodes lasting four days or more in all three regions from 2015 to 2020.

7. Line 117: The decrease in 2020 suggests correlation with emissions…

Response:

In line 117, we simply provide a brief description of the number of exceedance days and O_3 concentrations for each year, without delving into the analysis of the underlying causes at this point. Based on our subsequent analysis, the decrease observed in 2020 was primarily attributed to changing meteorological conditions.

8. Line 118: For completeness, please define "p" before use.

Response:

Thanks. Since p-value rather than "p" is a well-known terminology in statistical analysis, we have changed to "p-value" instead of "p" in the revised manuscript.

9. Line 127: "Is it due to changing O_3 photochemical processes or changing meteorological parameters?" – still the big question!

Response:

Yes, indeed! We also noticed that this sentence would be clearer if it is changed to "Is it due to changing emissions of air pollutants or changing meteorological parameters?" We have made the change in the revised manuscript.

10. Line 137: How does this expansion correlate with the expansion of urban/industrial regions to not previously developed regions (perhaps industries were relocated to surrounding regions from urban centerers?)

Response:

Please refer to our response to your general comment #2.

The expansion has been addressed specifically as follows: "We propose that the O_3 concentrations at the high O_3 stations stayed close to a saturation level of about 100 ppb throughout 2015 to 2020, even under downdrafts and stable atmospheric conditions brought about by mid-distance category TCs, was the result of a relatively high rates of atmospheric dispersion, dry deposition, and photochemical loss at high O_3 concentrations. This proposal is supported by modeling results (Li et al., 2012; Ouyang et al., 2022; Zhang et al., 2023). It is also consistent with theoretical consideration. While the low O_3 stations, where O_3 production were relatively small in 2015, experienced significant enhancements in the O_3 production (32 ppb in BTH, 12 ppb in PRD) from 2015 to 2017 because in 2017 the downdrafts and stable atmospheric conditions, which were highly conducive to O_3 formation, became more extensive due to changes in TCs and WPSH in the northwestern Pacific (Hu W. et al., 2023)."

11. Lines 141 to 144: Why compare the entire 2015-2020 period for high O_3 stations to the sub-period 2015-2017 for low O_3 stations?

Response:

Because "O_3 concentrations at the low O_3 stations caught up within 12 ppb with other stations in merely two years (an increase of about 30 ppb from 2015 to 2017), and actually equaled the average of other stations in 2019" as stated around lines 132 to 134 in the original manuscript.

12. Line 144: “quasi-saturation” – define.

Response:

Because both reviewers question the word “quasi-saturation”, we have changed it to simply “saturation”.

13. Line 145: “approximately 100 ppb” - what are the instrumental/measurement limitations for these sites?

Response:

According to “Environmental protection standards of the People’s Republic of China Ambient air – Automatic determination of ozone – Chemiluminescence method (HJ 1225-2021)”, the instrumental/measurement detection limit for O_3 is 0–500 ppb.

14. Line 147: “Did it have anything to do with the increase of consecutive O_3-exceeding days” – correlation!

Response:

No. Our analysis indeed began with correlation analysis. Once we observed correlations between different variables, we then seek theoretical support to explain this correlation and succeeded in most cases (Please refer to our response to your general comment #2).

15. Line 154: “expanded by about a factor of five from 2015 to 2017.” - how did the land use/development change during this period?

Response:

Please see our response to your general comment #3.

16. Line 155: how big in area is the BTH box? How does it compare to the resolution of the data you analyzed?

Response:

The BTH box encompasses 218000 km^2. The spatial resolution of TAP data is 10 km, approximate 2180 grids used in the BTH box.

17. Line 156: "66.42 ppb in 2015 (31 days, Fig. 5a) to 69.44 in 2017 (62 days, Fig. 5b)" - comparing averages over different time periods (and number of days), how do you justify this comparison?

Response:

We apologize if this has caused any confusion. To the best of our knowledge, comparing O_3 pollution between different years, whether it's comparing O_3 exceedance concentrations or the number of exceedance days, is a common analytical approach. Regarding O_3 exceedance concentrations, the difference between 2017 and 2015 was 3.02 ppb. In terms of the number of O_3 exceedance days, there were 31 more days of O_3 exceedance in 2017 compared to 2015. We believe that this comparative approach is reasonable.

Furthermore, we consider both the number of O_3 exceedance days and O_3 exceedance concentrations as they together constitute the intensity of O_3 exceedance. This is why we use normalized O_3 concentrations to reveal the contribution of O_3 exceedance conditions to the mean O_3 concentration of the entire year.

18. Line 159: Not clear what the equation represents. Consider labeling with variables and defining the equation prior to usage….

Response:

We have replaced all calculation formulas in the revised manuscript with textual explanations.

19. Line 162: "driven primarily by the increase of consecutive O_3-exceeding days" – correlation!

Response:

We arrived at this conclusion by comparing the contributions of O_3 exceedance concentrations and the contributions of the number of O_3 exceedance days, rather than through correlation analysis. Please refer to our response to your general comment #2.

20. Line 163: "a lion's share…" – consider revising the wording!

Response:

We have changed "a lion's share" into "a predominant portion" in the revised manuscript.

21. Line 165: What do you mean by quasi-saturation? How does it work? What is the mechanism preventing further increase in concentrations? Related to measurement limitations at the stations?

Response:

In this study, "quasi-saturation" refers to the phenomenon that O_3 concentration becomes nearly saturated and stops increasing after reaching certain level (approximate 100 ppb). The next two questions are addressed in our response to your specific comment #10.

On the question "Related to measurement limitations at the station?" Environmental protection standards of the People's Republic of China Ambient air – Automatic determination of ozone – Chemiluminescence method (HJ 1225-2021)", the instrumental/measurement detection limit for O_3 is 0–500 ppb, which has nothing to do with the quasi-saturation phenomenon.

22. Line 166: "suggested that there was a quasi-saturation of O_3 inside Beijing City, and an expansion of weather systems conducive to O_3 formation from Beijing toward the southwest of the BTH box during 2017" - So the weather systems conducive to O_3 formation were previously focused on urban centers and now it has expanded to surrounding regions?! Please comment.

Response:

Thank you for a very insightful comment. Please refer to our response to your general comment #2. In particular, Fig. 13 illustrates for BTH “the weather systems conducive to O_3 formation were previously focused on urban centers and now it has expanded to surrounding regions?!”.

23. Line 177: “Since it is highly unlikely” – please explain with data (e.g., emissions, land use/development) why it is highly unlikely!

Response:

Reviewer 1 had the same concern. We address this concern in the revised manuscript by consolidating and elaborating statements in “lines 166–168, 178–180, and many others” into a new section in line 243 as shown below.

“3.3.1 Changing emissions as a possible cause of O_3 trends in 2015–2020

As mentioned earlier, two emission-oriented hypotheses have been proposed as a possible cause of the O_3 trends in 2015–2020. One is changing emissions of O_3 precursors NOx and VOC (Li et al., 2022). The other is the reduced removal of HO_2 radicals by diminishing $PM_{2.5}$ suggested by Li K. et al. (2021) and Shao et al. (2021). Li et al. (2022) demonstrated convincingly that the NO titration effect was the cause of the linear trend in O_3 in PRD (0.5 ppb yr^{-1}) during the period 2006–2019. But for the period 2015–2020, the NO titration effect could account for only about 10% of the linear trend in O_3 of the low O_3 stations in PRD (5.0 ppb yr^{-1}, green line, Fig. S3a).

The increase of 30 ppb in O_3 at the low O_3 stations in BTH from 2015 to 2017 (green line, Figs. 4a and 8a represents about 50% increase in O_3. The titration effect can account for only about 5% (Fig. 8f). If this increase of 30 ppb in O_3 were due to an enhancement in O_3 precursors, the enhancement would have to be substantially greater than 50% because of the well-known less-than-linear relationship between changes in O_3 and its precursors, i.e., substantially more percentage changes in precursors are needed for each percentage change in O_3 (Dodge, 1977; Shafer and Seinfeld, 1985). Figs. 8d and 8f show that CO (a proxy for VOC) and NOx changed only by a few percent from 2015 to 2017, more than one order of magnitude less than the changes needed. Hence it appears that changes in meteorological conditions conducive to O_3 formation are more likely the major contributing factor to the 50% increase in O_3 at the low O_3 stations in BTH. Similar argument can be extended to YRD and PRD (Figs. S1 and S3).

The theory of reduced removal of HO_2 radicals by diminishing $PM_{2.5}$ (25%, green line of Fig. 8c) appeared to be valid qualitatively for the 50% increase in O_3 at the low O_3 stations in BTH from 2015 to 2017 (green line of Fig. 8a). But this theory was contradicted directly by the phenomenon at the high O_3 stations where a 30% reduction in $PM_{2.5}$ (red line of Fig. 8c) corresponded to a decrease rather than an increase in O_3 (red line of Fig. 8a)."

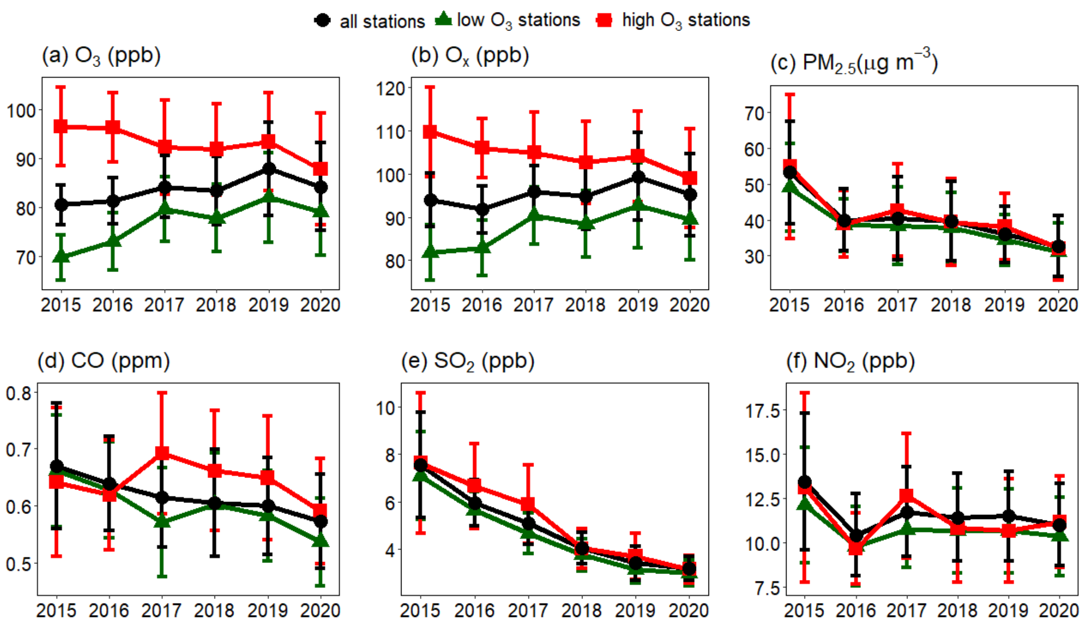

Figure S1. Annual mean concentrations of maximum daily 8-hour average O_3 in YRD during O_3-exceeding days for all stations (black), high O_3 stations (red) and low O_3 stations (green) (a), same as (a) except for Ox (b), $PM_{2.5}$ (c), CO (d), SO_2 (e), NO_2 (f).

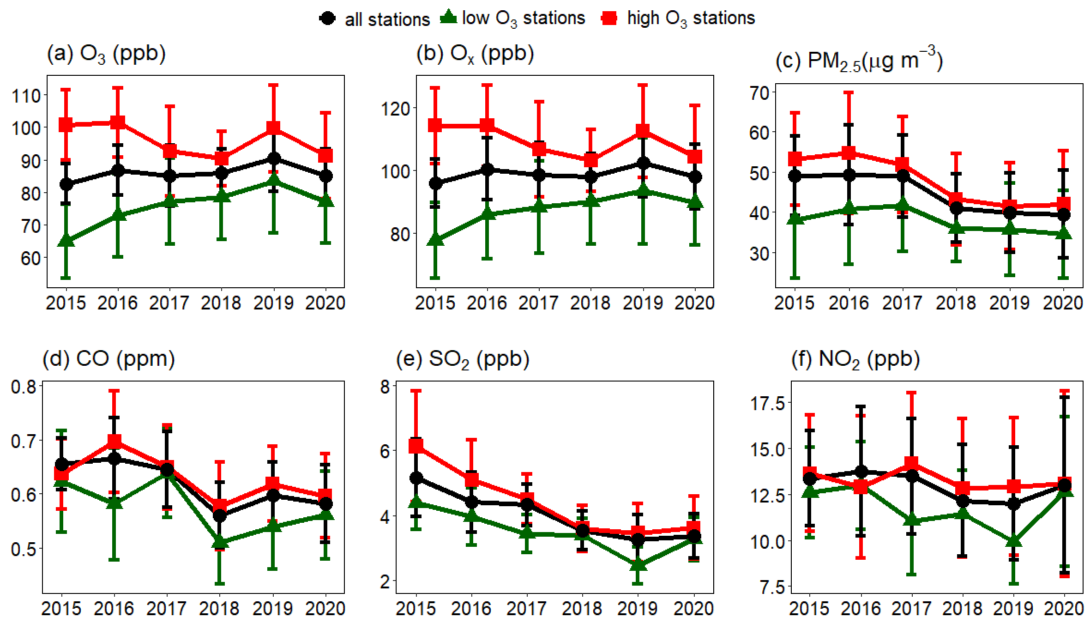

Figure S3. Annual mean concentrations of maximum daily 8-hour average O_3 in PRD during O_3-exceeding days for all stations (black), high O_3 stations (red) and low O_3 stations (green) (a), same as (a) except for Ox (b), $PM_{2.5}$ (c), CO (d), SO_2 (e), NO_2 (f).

24. Line 249: "into two groups" – why these two groups?

Response:

Please see our response to your specific comment #6.

25. Line 327: include full forms in the section titles rather than acronyms.

Response:

Done accordingly.

26. Line 320-323: So, the increased ozone is due to reduction in removing processes (low advection and low mixing) while the production is the same and not increased?

Response:

The downdrafts and stable atmospheric conditions are usually associated with meteorological conditions of clear skies and high surface temperatures which are highly conducive to higher photochemical production as well as reduced "removing processes (low advection and low mixing)" of O_3. Please refer to our response to your general comment #2.

27. Line 343: "… in the former" - do you mean O_3 exceeding days?

Yes, "… in the former" means O_3-exceeding days. To avoid confusion, we have replaced the former with "O_3 exceeding days", and the latter with "clean days" in the revised manuscript.

28. Please comment on your choice for compare the average conditions over (for example) 31 days for O_3 exceeding days to average over 152 clear days? What happens if you compare O_3 exceeding days to average over the entire period including both clear days and O_3 exceeding days?

Response:

Comparing the average conditions over all O_3-exceeding days to the average over 152 clean days is aimed at providing an intuitive analysis of the differences in meteorological patterns between polluted and clean days.

Following your suggestion, we have also compared O_3 exceeding days to average over the entire period including both clear days and O_3 exceeding days, as shown in Fig. S11. It is clear that this additional comparison does not affect the validity of our conclusions.

29. Fig 12: what does the concentration in ppb in parentheses refer to? Figure details are not clear (e.g., isoline labels are hard to read, 5880 gpm is not even labeled)

Response:

The concentration in ppb in parentheses refer to average O_3 concentration. We have revised all the figures in the revised manuscript.

Technical corrections:

1. I suggest using different markers in Figures 1,2, and 4, so that different curves are discernible on a grayscale (black and white) version of your manuscript.

Response:

Done accordingly.

2. Table 3, 4: write complete captions rather than "same as…"

Response:

Done accordingly.

3. Figures 5,6: complete the captions.

Response:

Done accordingly.

4. Line 478 and 492: hyperlinks don't work, please check!

Response:

Checked.

References

Chang, L., Xu, J., Tie, X., and Gao, W.: The impact of Climate Change on the Western Pacific Subtropical High and the related ozone pollution in Shanghai, China, Sci. Rep., 9, 16998, https://doi.org/10.1038/s41598-019-53103-7, 2019.

Huang, Y., Zhou, J., Yu, Y., Mok, W.-C., Lee, C. F. C. and Yam, Y.-S.: Uncertainly in the impact of the COVID-19 pandemic on air quality in Hong Kong, China, Atmosphere, 11, 914, https://doi.org/10.3390/atmos11090914, 2020.

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